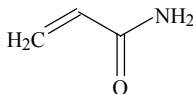


ACRYLAMIDE
CAS No. 79-06-1

First Listed in the *Sixth Annual Report on Carcinogens*



CARCINOGENICITY

Acrylamide is *reasonably anticipated to be a human carcinogen* based on sufficient evidence of carcinogenicity in experimental animals (IARC V.39, 1986; IARC S.7, 1987). When administered in the drinking water, acrylamide increased the incidences of adrenal pheochromocytomas and mesotheliomas of the tunica of the testes in male rats; pituitary adenomas, mammary adenomas and adenocarcinomas, oral cavity papillomas, uterine adenocarcinomas, and clitoral gland adenomas in female rats; and follicular adenomas of the thyroid in rats of both sexes. When administered by gavage or by intraperitoneal injection, acrylamide increased both the incidence and multiplicity of lung adenomas in mice of both sexes. When administered topically, by gavage, or by intraperitoneal injection followed by long-term topical treatment with 12-*o*-tetradecanoylphorbol-13-acetate, acrylamide induced skin squamous cell papillomas and squamous cell carcinomas in female mice.

There are no adequate data available to evaluate the carcinogenicity of acrylamide in humans (IARC V.39, 1986; IARC S.7, 1987).

PROPERTIES

Acrylamide occurs in crystalline form and in aqueous solution. The solid monomer is a colorless-to-white, free-flowing crystal that is soluble in water, methanol, ethanol, dimethyl ether, and acetone and is insoluble in benzene and heptane. It melts at 84-85 °C and boils at 125 °C. The crystalline acrylamide monomer is available as pellets of 98% and 95% purity. The 50% aqueous form is the preferred form for applications in which water can be tolerated. The monomer readily polymerizes at the melting point or under ultraviolet light. Solid acrylamide is stable at room temperature but may polymerize violently when melted or in contact with oxidizing agents. When heated to decomposition, acrylamide emits acrid fumes and nitrogen oxides (NO_x). Commercial acrylamide monomer contains residual levels of acrylonitrile (1-100 mg/kg) (IARC V.39, 1986). Residual acrylamide monomer is present in the polymer at approximately 0.01% (Fujiki et al., 1985; IARC V.39, 1986).

USE

Acrylamide is a chemical intermediate used in the production and synthesis of polyacrylamides (IARC V.39, 1986). These high-molecular weight polymers can be modified to develop nonionic, anionic, or cationic properties for specific uses. The principle end use of acrylamide is in water-soluble polymers used as additives for water treatment, enhanced oil recovery, flocculants, papermaking aids, thickeners, soil conditioning agents, sewage and waste treatment, ore processing, and permanent-press fabrics (Kirk-Othmer V.1, 1978; Sax and Lewis, 1987). Acrylamide is also used in the synthesis of dyes, in copolymers for contact lenses, and the construction of dam foundations, tunnels, and sewers (Kirk-Othmer V.6, 1979).

The largest use for polyacrylamide is in treating municipal drinking water and waste water (IARC V.39, 1986). The polymer is also used to remove suspended solids from industrial waste water before discharge, reuse, or disposal. Polyacrylamide used for potable water should not contain more than 0.05% residual monomer (Kirk-Othmer V.1, 1978). The polymers bind with particles and form heavy aggregates that rapidly settle out of solution and leave a clear supernatant (IARC V.39, 1986). Ten to thirty percent of the annual production volume is used in oil-recovery processes in which the polyacrylamides increase water viscosity. Acrylamides also find use in oil-drilling processes to control fluid losses. In the pulp and paper industry, polyacrylamides are used as binders and retention aids for fibers and to retain pigments on paper fibers. The paper industry uses approximately 20% of the annual U.S. production volume. Polyacrylamides are used to clarify waste water, recover tailings, and flocculate ores in mineral processing. They are incorporated in cement to slow the dehydration process to improve structural strength. Methylated polyacrylamide with subsequent radiation curing is used to produce waterproof concrete. Acrylamide is a soil stabilizer and also finds use in foundry operations to facilitate free sand flow into molds. Polyacrylamides are incorporated in coatings as dispersants and binders and in water-based paints for pigment suspension and flow. Home appliances, building materials, and automotive parts are coated with acrylamide resins and thermosetting acrylics. Acrylamides are formulated in cosmetics and soap preparations as thickeners and in dental fixtures, hair grooming preparations, and preshave lotions. In the textile industry, polyacrylamides are used to size and shrink-proof material and as water repellents. Minor uses of acrylamide are as latex thickeners, emulsion stabilizers for printing inks, gelling agents for explosives, binders in adhesives and adhesive tape; in the production of diazo compounds; and for gel chromatography and electrophoresis (Sittig, 1985; IARC V.39, 1986). When added to herbicidal gels, polyacrylamides restrict herbicidal treatment to the bottom of lakes or reservoirs by allowing the herbicides to sink before they break up. The FDA has regulated the use of acrylamide and polyacrylamide in foods. Up to 10 mg polyacrylamide/L water can be used to wash or peel fruits and vegetables; acrylamide monomer should not exceed 0.2%. Acrylamide resins may be added to water for steam that will contact food; the monomer should not exceed 0.05% by weight. Polyacrylamide may be used in gelatin capsules, if no more than 0.2% of the monomer is present. Acrylamide polymers may be used in food packaging adhesives, and acrylamide resins, containing < 0.2% monomer, may be used in food packaging paper and paperboard if the resin is $\leq 2\%$ of the weight of the paper.

PRODUCTION

Currently, there are 14 U.S. suppliers of acrylamide listed in *Chemcyclopedia* 98 (Rodnan, 1997). The 1998 *Chemical Buyers Directory* names nine such companies (Tilton, 1997). The 1997 *Directory of Chemical Producers* lists four producers of the compound, with a total output of 217 million lb (SRIa, 1997). Two U.S. manufacturers of acrylamide monomer were identified for 1994 without any production values (USITC, 1995). In 1992, three manufacturers were reported to produce 113.5 million lb of the chemical (USITC, 1994). Two producers for acrylamide monomer were listed by USITC (1993, 1991) for 1991 and 1990, and three producers for 1988 (USITC, 1989), without any production figures. Four U.S. producers reportedly manufactured 47.1 million lb in 1986 (USITC, 1987), and an estimated 70 million lb was produced in 1974 (Sittig, 1985).

For 1992, U.S. imports totaled 15 million lb and exports were estimated to be less than 2 million lb (OPPT, EPA, 1994). Twenty years earlier, the volumes were considered negligible (HSDB, 1997).

EXPOSURE

Acrylamide can be absorbed through unbroken skin (Merck, 1989), mucous membranes and lungs, and the gastrointestinal tract (Klaassen et al., 1986). NIOSH estimates that approximately 20,000 workers were potentially exposed to acrylamide in 1976 (IARC V.39, 1986). Human exposure to acrylamide is primarily occupational from dermal contact with the solid monomer and inhalation of dust and vapor (Kirk-Othmer V.1, 1978; Howard, 1989). Occupational exposure to the aqueous form is primarily confined to maintenance and repair operations and connection and disconnection for transport. Routine exposure is minimal for captive operations. Polymerized acrylamide is not toxic, but the monomer can cause peripheral neuropathy (Klaassen et al., 1986). Residual monomer in the polymers is a concern (Howard, 1989). Improvements in the polymerization process have reduced the monomer content of the nonpotable water-grade polymers from 5% to 0.3% (Brown et al., 1982).

Workers in the paper and pulp, construction, foundry, oil drilling, textiles, cosmetics, food processing, plastics, mining, and agricultural industries are potentially exposed to acrylamide. Although exposure levels have not been reported for grouters, the potential exposure for these personnel may be greater than for other workers because of the uncontrolled nature of the exposure (WHO, 1985). The National Occupational Health Survey (1972-1974) estimated that 10,368 workers were exposed to acrylamide (Howard, 1989). The National Occupational Exposure Survey (1981-1983) estimated that 9,776 workers potentially were exposed (NIOSH, 1984). This estimate was based on observations of actual use of the chemical (43%) and as an ingredient of tradename products (57%).

Primary exposure occurs during the handling of the monomer. Two acrylamide manufacturing plants showed breathing zone concentrations of 0.1-3.6 mg/m³ (IARC V.39, 1986). During normal operations, workers at another plant were exposed to not more than 0.3 mg/m³. The ACGIH (1996) recommended a threshold limit value (TLV) of 0.03 mg/m³ with no short-term exposure limit for acrylamide.

Although human exposure to acrylamide will primarily be occupational, the general public may be exposed through contaminated drinking water from polyacrylamide flocculants used in water treatment (Brown et al., 1980a; Howard, 1989). Residual acrylamide concentrations in 32 polyacrylamide flocculants approved for water treatment plants ranged from 0.5 to 600 ppm (Howard, 1989). Acrylamide may not be removed in many water treatment processes (Croll et al., 1974). Acrylamide remains in water after flocculation with polyacrylamides because it is very water soluble and is not readily adsorbed by sediment (Brown et al., 1980b). Acrylamide and polyacrylamides are used in the manufacture of a number of consumer products, including textiles, contact lenses, appliances, building materials, cosmetic and soap preparations, food, and gelatin capsules (Kirk-Othmer V.6, 1979).

Acrylamide may be released into the environment from waste during acrylamide production and the manufacture of polyacrylamides and other polymers (Howard, 1989). Release to water also occurs from acrylamide-based sewer grouting and wastepaper recycling (Brown et al., 1980b, 1982; Howard, 1989). The most important environmental contamination results from the use of acrylamide in soil grouting (WHO, 1985). Acrylamide biodegrades in water in approximately 8-12 days (Howard, 1989). Acrylamide may not be completely degraded in sewage works and water treatment facilities if residence times are relatively short (Brown et al., 1982; Howard, 1989). Acrylamide degradation in a secondary sewage plant would be complete in approximately 10 days (Kirk-Othmer V.1, 1978). It has been detected in effluent from a sewage treatment plant. Adsorption to sediment and volatilization is not appreciable. Certain debris organisms that exist in anaerobic, light aerobic, or dark aerobic conditions in natural

and polluted environments are able to degrade acrylamide (Brown et al., 1980b). Bacteriologic degradation will likely depend on temperature fluctuations in temperate climates. Although acrylamide is highly mobile in aqueous environments, readily leaches into soil, and is carried great distances in ground water of deep rock aquifers where biodegradability is reportedly absent (WHO, 1985), bioconcentration of acrylamide is unlikely because it degrades easily in surface waters and is highly water soluble (Kirk-Othmer V.1, 1978). In an EPA study of five industrial sites (beyond plant site perimeters) of acrylamide and polyacrylamide producers and one polyacrylamide user, acrylamide (1.5 ppm) was found in only one sample downstream from a polyacrylamide producer; no acrylamide was detected in soil or air samples (WHO, 1985; Howard, 1989). An average acrylamide concentration in air was $< 0.2 \mu\text{g}/\text{m}^3$ near six acrylamide or polyacrylamide plants. The vapor pressure of acrylamide is low, and the monomer is not expected to be distributed in the atmosphere (WHO, 1985).

Environmental contamination may result from disposal on land or from leaching of the residual monomer from polyacrylamides. The Toxic Chemical Release Inventory (EPA) estimated that 5,912,663 lb of acrylamide were released to the environment from 43 facilities that produced, processed, or used the chemical in the United States in 1996. Of that total, 97.2% was released to underground injection. Thirty-nine facilities were responsible for the 11,700 lb of acrylamide emitted to air. Eleven facilities, each releasing > 100 lb to air, represented 94.8% of the total emission; one facility located in Greensboro, North Carolina, reporting under industrial classifications for manufacture of surface active agents (SIC Code 2843) and soap and other detergents (SIC Code 2841) and releasing > 1000 lb of acrylamide, accounted for 63.0% of total air releases. Other 1996 total releases were 3,653 lb to water and 149,156 lb to land (TRI96, 1998).

REGULATIONS

EPA regulates acrylamide under the Clean Air Act (CAA), Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), Resource Conservation and Recovery Act (RCRA), Safe Drinking Water Act (SDWA), and Superfund Amendments and Reauthorization Act (SARA). Substituted acrylamide and polymers containing the compound are regulated by the Toxic Substances Control Act (TSCA). Acrylamide is a toxic pollutant of air and water. EPA has established rules for regulating hazardous spills, general threshold amounts, and requirements for handling and disposal of wastes. A reportable quantity (RQ) of 5,000 lb has been established for acrylamide under CERCLA. It, furthermore, is regulated as a hazardous constituent of waste under RCRA. A maximum contaminant level goal (MCLG) of 0 mg/L and a water treatment technique for acrylamide has been promulgated by EPA under SDWA. FDA, under the Food, Drug, and Cosmetic Act (FD&CA), regulates acrylamide as an indirect food additive. The NIOSH Pocket Guide to Chemical Hazards lists the recommended criteria for the time-weighted average (TWA) for exposure to workroom air for a 40-hr work week as $0.03 \text{ mg}/\text{m}^3$ acrylamide. The OSHA final rule permissible exposure limit (PEL) was reduced from $0.3 \text{ mg}/\text{m}^3$ to $0.03 \text{ mg}/\text{m}^3$ for an 8-hr TWA; the potential for skin absorption was noted. OSHA also regulates acrylamide as a chemical hazard in laboratories under the Hazard Communication Standard. Regulations are summarized in Volume II, Table B-3.